P2001,0082
Application No. 10/637,191

CERTIFICATION

I, the below named translator, hereby declare that: my name and post office address are as stated below; that I am knowledgeable in the English and German languages, and that I believe that the attached text is a true and complete translation of German application DE 101 05 722.9, filed with the German Patent Office on February 8, 2001.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Description

Semiconductor laser

The invention relates to a semiconductor laser having a vertical resonator formed by reflectors, having a photon-emitting active layer arranged between the reflectors and having a current diaphragm for laterally circumscribing the current flowing through the active layer.

Semiconductor lasers of this type are known as so-called VCSELs (Vertical Cavity Surface-Emitting Laser). These semiconductor lasers have a layer sequence comprising an active layer enclosed between two DBR mirrors (distributed Bragg reflector). In order to delimit the current injected into the active layer in the lateral direction, provision is made of a current diaphragm composed of an oxide in one of the DBR mirrors. The current diaphragms define a current aperture with their inner edge and limit the lateral extent of the pump spot diameter in the active layer.

In principle, monomode operation is also possible with semiconductor lasers of this type. However, this requires a comparatively small pump spot diameter of less than 4 µm, which necessitates a correspondingly small current aperture. However, such small diameters of the current aperture can be produced precisely only with great difficulties. The oxidation is usually effected laterally from the edges of the layer sequence after the layer sequence has been completely deposited. However, this procedure requires accurate knowledge and control of the process parameters.

Moreover, on account of the small current aperture, the known semiconductor lasers with current diaphragms composed of oxide have low optical output powers, high nonreactive resistances and high thermal resistances.

Taking this prior art as a departure point, the invention is based on the object of providing a simple-to-produce monomode semiconductor laser having high optical output power and low nonreactive and thermal resistance.

This object is achieved according to the invention by virtue of the fact that further mode-selective regions, which extend in the vertical direction and laterally delimit the vertical resonator, are present in addition to the current diaphragm.

The additional mode-selective regions along the axis of the vertical resonator effectively suppress higher modes, since the latter incur higher losses than the fundamental mode in the mode-selective regions. Therefore, only the fundamental mode can reach the laser threshold. At the same time, it is possible to enlarge the current aperture, which, in comparison with the prior art, results in a higher output power and a lower nonreactive and thermal resistance.

In a preferred embodiment of the invention, the mode-selective regions are implantation regions with reduced conductivity.

Such implantation regions can also be formed with sufficient precision in a large volume. Moreover, the conductivity can be lowered by means of implantations, thereby attenuating higher-order lateral modes in the implantation regions.

The dependent claims relate to further advantageous refinements of the invention.

The invention is explained in detail below with reference to the accompanying drawing, in which:

Fig. 1 shows a cross section through a semiconductor laser according to the invention.

The semiconductor laser 1 illustrated in cross section in Fig. 1 has a lower Bragg reflector 3 applied to a substrate, a cavity 4 with a photon-emitting active zone being formed on said reflector. Situated above the cavity 4 is an upper Bragg reflector 5, in which current diaphragms 6 are formed. The inner edge of the current diaphragms 6 defines current apertures 7 delimiting the lateral extent of the currents injected into the cavity 4. As a result, a photon-emitting pump spot 8 is produced in the cavity 4, which pump spot optically amplifies the radiation reflected between the lower Bragg reflector 3 and the upper Bragg reflector 5. Part of this radiation is allowed to pass by the upper Bragg reflector 5 and can leave the semiconductor laser 1 through an exit opening 9 in an annular front side contact 10. A rear side contact 11 is additionally present on the rear side of the substrate 2.

Generally, the upper Bragg reflector 5 is designed as a mesa 12. Situated in edge regions of the mesa 12 are implantation regions 13, which also extend into the substrate 2. The implantation regions 13 have an inner opening 14. The cross-sectional area of the inner opening 14 is always larger than the area of the current apertures 7.

By means of implantation, the conductivity of the material in the implantation regions 13 is less than the conductivity in the inner opening 14 of the implantation regions 13. Higher-order modes, which extend into the implantation regions 13 are therefore attenuated. An optical amplification takes place only in the region of the inner opening 14, that is to say in the region of the fundamental mode. Therefore, the diameter of the current apertures 7 can be chosen to be larger than in the prior art.

The larger opening of the current apertures 7 in comparison with the prior art leads to a lower series resistance of the semiconductor laser 1, and to a lower thermal resistance, which results in weaker ageing effects. Moreover, the large current apertures 7 lead to a large pump spot and thus to higher optical output powers. The inner diameter of the current apertures 7 is more than 3 μm, preferably more than 4 μm, in the semiconductor laser 1.

What is also particularly advantageous is that the production of the current diaphragms 6 can be controlled better in comparison with the prior art, since the production-dictated deviations during the production of the current diaphragms 6 are smaller as seen in relative terms.

The double embodiment of the current diaphragms 6 furthermore makes it possible to avoid excessive edge elevations of the current injection into the cavity 4 which intrinsically also jeopardize the monomode nature.

The invention described here is not restricted to specific materials. The known materials that can be used for the type

of semiconductor lasers 1 described can be considered. The customary methods known to the person skilled in the art are suitable for production.

Patent claims

1. A semiconductor laser having a vertical resonator formed by reflectors (3, 5), having a photon-emitting active layer (8) arranged between the reflectors (3, 5) and having a current diaphragm (6) for laterally circumscribing the current flowing through the active layer (8),
characterized in that
further mode-selective regions (13), which extend in the vertical direction and laterally delimit the vertical resonator, are present in addition to the current diaphragm (6).

2. The semiconductor laser as claimed in claim 1,
characterized in that
the reflector is formed in a mesa (12).

3. The semiconductor laser as claimed in claim 1 or 2,
characterized in that
the mesa (12) has a diameter of > 10 μm.

4. The semiconductor laser as claimed in one of claims 1 to 2,
characterized in that
the current diaphragm (6) is produced from oxide.

5. The semiconductor laser as claimed in one of claims 1 to 4,
characterized in that
the current aperture (7) formed by the current diaphragms (6) has a diameter of > 3 μm.

6. The semiconductor laser as claimed in claim 5,
characterized in that
the current diaphragm (6) has a diameter of > 4 μm.

7. The semiconductor laser as claimed in one of claims 1 to 6,
characterized in that
an inner opening (14) of the mode-selective regions (13) is larger than the current aperture (7).

8. The semiconductor laser as claimed in one of claims 1 to 7,
characterized in that
the mode-selective regions (13) have a conductivity which is less than a conductivity of the vertical resonator along the resonator axis.

9. The semiconductor laser as claimed in one of claims 1 to 8,
characterized in that
the mode-selective region is an implantation region (13).

10. The semiconductor laser as claimed in claim 9,
characterized in that
the implantation region (13) extends in the edge and surrounding region of the vertical resonator.

Abstract

Semiconductor laser

A semiconductor laser has implantation regions which are effective as mode-selective regions (13) in addition to current diaphragms (6) in the edge region of a mesa (12). As a result, the inner opening of the current diaphragms (6) can be chosen to be larger than in the prior art. This leads to a low ohmic and thermal resistance and enables a high output power.

Fig. 1